ChemMatters®

DEMYSTIFYING EVERYDAY CHEMISTRY

APRIL 2008

The Quest for a Clean Drink

Interview With Nobel Prize Winner Gerhard Ertl, page 18

CM Demystifying Everyday Chemistry

Production Team
Patrice Pages, *Editor*
Cornithia Harris, *Art Director*
Leona Kanaskie, *Copy Editor*

Administrative Team
Terri Taylor, *Administrative Editor*
Saundra Barlow, *Senior Program Associate*
Peter Isikoff, *Administrative Associate*

Technical Review
Seth Brown, *University of Notre Dame*
David Voss, *Medina High School, Barker, NY*

Teacher's Guide
William Bleam, *Editor*
Donald McKinney, *Editor*
Mark Michalovic, *Editor*
Ronald Tempest, *Editor*
Susan Cooper, *Content Reading Consultant*
David Olney, *Puzzle Contributor*

Education Division
Mary Kirchhoff, *Director*

Policy Board
Ingrid Montes, Chair, *University of Puerto Rico*
Ron Perkins, *Educational Innovations, Inc., Norwalk, CT*
Barbara Sitzman, *Tarzana, CA*
Susan Gleason, *Middletown, DE*
Mark Meszaros, *Batavia, IL*

ChemMatters (ISSN 0736–4687) is published four times a year (Oct., Dec., Feb., and Apr.) by the American Chemical Society at 1155 16th St., NW, Washington, DC 20036–4800. Periodicals postage paid at Washington, DC, and additional mailing offices. POSTMASTER: Send address changes to *ChemMatters Magazine*, ACS Office of Society Services, 1155 16th Street, NW, Washington, DC 20036.

Subscriber Information
Prices to the United States, Canada, and Mexico: $14.00 per subscription. Inquire about bulk, other foreign rates, and back issues at ACS Office of Society Services, 1155 16th Street, NW, Washington, DC 20036; 800-227-5558 or 202-872-6067 fax. Information is also available online at http://chemistry.org/education/

MIKE CIESIELSKI

QUESTION FROM THE CLASSROOM, Part II

By Bob Becker

Q. My lab partner accidentally heated a regular glass test tube over a Bunsen burner, and it cracked right away. The teacher said that he was supposed to be using a Pyrex test tube. Why does regular glass shatter when it's heated but Pyrex glass does not?

A. You have probably learned that things expand when they are heated. This is due to the fact that the increase in temperature corresponds to an increase in particle kinetic energy, and as the particles move faster, they also move farther apart.

For gases, the relationship—also called Charles' law—is direct: A doubling of temperature (in degrees Kelvin (K)) leads to a doubling of volume. For solids, the change is not nearly as dramatic. Since the particles are bonded to one another, the temperature increase just causes a slight lengthening of each bond.

To illustrate this, if a 2-centimeter (cm)-diameter sphere of a gas (a small bubble of air, for example) undergoes a temperature increase from room temperature, that is, from 25°C (or 298 K) to 323°C (or 596 K), the sphere's diameter increases to 2.52 cm. A 2-cm-diameter sphere of a solid—such as regular glass—undergoing the same temperature change ends up with a diameter of 2.0017 cm. Such a tiny change would be impossible to see!

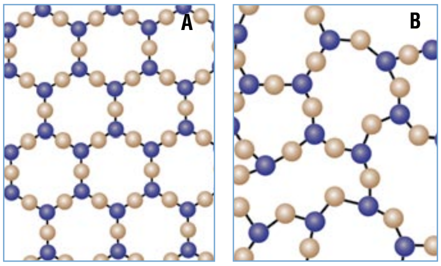
So what causes a sphere of glass to shatter? The expansion mentioned above happens when temperature is raised over the entire sphere. Glass does not conduct heat very well, so when a piece of glass is heated very quickly, the outer portion gets hot and expands before the inner portion does.

Having part of a rigid object expanding while another part is not expanding can cause all kinds of internal stress and strain. If these stresses are great enough, they can break the bonds between the atoms and cause the glass to crack. That is what happened to your lab partner's test tube. And although an expansion of 0.0017 cm may seem insignificant, it is about 60,000 to 80,000 times the distance between two atoms in glass.

But glass is an unusual material. The atoms in glass—mostly oxygen, silicon, sodium, and calcium—are not arranged in an orderly crystalline pattern, as they are in most solids.

Instead, they are randomly arranged into what is called an "amorphous" solid (Amorphous means "without form.").

But why does a Pyrex test tube not shatter when it is quickly heated? Simple: Pyrex glass does not expand nearly as much when it is heated.



ANTHONY FERNANDEZ

Unlike a crystal (A), where the atoms are arranged in a periodic way, in a glass (B), small variations in the way the bonds are arranged disrupt any long-range order.

Every substance can be characterized by a quantity called a linear coefficient of expansion (LCE) that indicates how much the thickness (or width or length) of a substance changes per degree Celsius.

Regular glass—also called soda lime glass—is made up of about 70% silica (SiO_2), about 10–15% sodium oxide (Na_2O), about 10% calcium oxide (CaO), and small amounts of other minor ingredients. Its LCE is 8.3 parts per million (ppm)/ °C.

Pyrex—which is actually a trade name for what is generically called "borosilicate" glass—contains many of the same components as soda lime glass, but it also contains at least 5% boric oxide (B_2O_3). The inclusion of boron atoms greatly reduces the LCE of the glass to 3.3 ppm/ °C. Because it doesn't expand as much, it is far less likely to break.

ChemMatters®
Vol. 26, No. 2 APRIL 2008

But a quick, very extreme temperature change will cause even a Pyrex container to crack. Taking a Pyrex test tube out of a hot burner flame, for example, and quenching it directly in cold water will definitely cause it to shatter.

More recently, special types of glass that are almost pure silica have been developed that have even lower LCE values and can therefore withstand even greater temperature changes. Zerodur—a fused silica glass developed by Corning Glass Co.—has an LCE of just 0.02 ppm/°C. Generally speaking, these ultra heat-resistant types of glass have extremely high melting points, making them difficult to work with, and this keeps their costs high.

MIKE CIESIELSKI

Glass (left) cracks more easily than Pyrex (right).

By the way, metallic objects are routinely heated to very high temperatures and then quenched in water without shattering. This might lead you to believe that metals have very low LCE values. In fact, their LCEs are quite high. Copper, for example, has an LCE of 17 ppm)/°C, and aluminum has an LCE of 23 ppm)/°C.

So why don't metals shatter like glass? One reason is that metals are very good conductors of heat, so a big temperature discrepancy within a metal object never occurs. Also, metals are very flexible. Because of metallic bonding, their atoms are quite good at slipping by one another without losing their attraction for one another.

REFERENCE

Mills, Walt. What Makes Glass Break? *ResearchPennState, The Online Magazine of Scholarship and Creativity*. **http://www.rps.psu.edu/probing/glass.html**

ABUL K.M. MUNIR

MOUNT HOLYOKE COLLEGE ARCHIVES AND SPECIAL COLLECTIONS

MIKE CIESIELSKI

FRITZ-HABER-INSTITUT DER MAX-PLANCK-GESELLSCHAFT

CHECK OUT OUR NEW WEB SITE AT WWW.ACS.ORG/CHEMMATTERS

COVER PHOTO CREDITS: MIKE CIESIELSKI, GETTY IMAGES, AND ABUL K. M. MUNIR

The Quest for a Clean Drink

ABUL K.M. MUNIR

Water in India and Bangladesh is contaminated with arsenic, but chemistry has solutions.

By Christen Brownlee

In the United States and many other countries, getting clean drinking water is relatively easy. Just turn on the tap and out it comes. But not everyone has it so lucky. In some countries, getting a glass of clean water is a luxury—and in a few places, such as India and Bangladesh, it could mean the difference between life and death. In these countries, located next to each other in Asia, the drinking water on which millions of citizens rely is contaminated with arsenic.

Enterprising scientists have recently devised ways to remove arsenic from drinking water. Three of them—Abul Hussam, associate professor of chemistry and biochemistry at George Mason University, Fairfax, VA; Arup K. SenGupta, professor of chemical engineering and of civil and environmental engineering at Lehigh University, Bethlehem, PA; and Phil Souter, a chemist at Procter & Gamble—along with their colleagues have been so successful that they have received awards worth $1 million, $200,000, and $100,000, respectively, by the prestigious National Academy of Engineering, Washington, DC.

The techniques created by these scientists are water purification systems that are both easy to use and affordable by the people who need them the most—those who live in some of the poorest areas of India and Bangladesh. These systems have worked so well that they are now distributed to an increasing number of locations throughout India and Bangladesh.

Contaminated and deadly water

Decades ago, the people of India and Bangladesh relied mostly on surface water, such as ponds, lakes, and rivers. Water from these sources helped cook their food, clean their bodies, and quench their thirst. But growing populations and bad sanitation resulted in tainted surface water, making people sick when they drank it.

In the 1970s, some engineers and aid organizations came up with what seemed to be a perfect way to avoid microbes, but they did not consider monitoring water quality. By drilling shallow wells called tube wells between 30 and 150 feet into the ground, people could access groundwater that had been naturally filtered through the soil and that did not contain microbes.

Unfortunately, groundwater from many areas contained inorganic arsenic species, called arsenite (H_3AsO_3) and arsenates

ABUL K.M. MUNIR

SONO filter created by Abul Hussam.

($H_2AsO_4^-$ and $HAsO_4^{2-}$), which are deadly chemicals. About 20 years later, tests showed that thousands of tube wells were pumping out water brimming with arsenic.

The three arsenic species are a natural part of rocks and soil, but they don't pollute the surface water because they bind to iron hydroxide ($Fe(OH)_3$), a compound abundant in soil. But underground, different types of bacteria reduce the ferric ion (Fe^{3+})—one of the two ions making up $Fe(OH)_3$: Fe^{3+} and OH^-—to ferrous ion (Fe^{2+}), which is more soluble than ferric ions and breaks apart from the arsenic, releasing it into the subsurface water.

The effects of arsenic from drinking water on human health are not immediate, but over time, the poisonous water can cause cancer and death. Hard, dark patches on the skin appear first and are followed by nerve damage, often in the hands and legs, which can lead to their amputation, as well as liver cancer and kidney failure. Over a few years, a person drinking arsenic-contaminated water often dies from arsenicosis, a type of slow arsenic poisoning.

Using buckets to make filters

When Hussam discovered that his own relatives—who live in a district of more than half a million people in a part of Bangladesh called Kushtia—had been drinking arsenic-laced water, he decided to find a solution. In 1997, he started measuring the water's arsenic content and developing a filtration system that could remove the toxic arsenic species pumped from tube wells.

Hussam and colleagues made a prototype filter that uses two buckets piled on top of each other. Water is first poured into the topmost bucket, and then it passes through a special material called a composite iron matrix, which is a mixture of iron and iron hydroxide.

Manganese in the matrix catalyzes the transformation of the more toxic arsenite to arsenate ions. These ions bind to the surface of iron hydroxide particles as follows:

$$-\overset{\diagdown}{\underset{\diagup}{Fe}} - OH + H_2AsO_4^- \rightarrow -\overset{\diagdown}{\underset{\diagup}{Fe}} - OAsO_3H^- + H_2O$$

$$-\overset{\diagdown}{\underset{\diagup}{Fe}} - OH + HAsO_4^{2-} \rightarrow -\overset{\diagdown}{\underset{\diagup}{Fe}} - AsO_4^{2-} + H_2O$$


ARUP K. SENGUPTA

Hand pump water treatment unit developed by Arup K. SenGupta.

In these chemical reactions, the arsenate ions are shown binding to hydroxide groups (–OH) present on the surface of the iron hydroxide particles, while the iron atoms (Fe) are bound to atoms inside each iron hydroxide particle (hence the lines referring to such bonds deep within each particle).

When the water goes through the second bucket, layers of sand and charcoal remove the solid iron hydroxide particles with their load of attached arsenic, along with other chemicals that were not trapped in the top filter. After crossing this second bucket, the water is then collected in a container.

"We didn't test this prototype filter in the lab—we tested it with real groundwater, right in the fields of Bangladesh," Hussam says. "We thought that if it works with water that people take home to drink, then we can continue working on it. Otherwise, we would have to go back and try something else."

Luckily, Hussam's prototype worked very well and after it was optimized in 2000, he and his team started manufacturing the filters in bulk. Now, more than 72,000 of these bucket filters have been distributed under the brand name SONO in Bangladesh. Each costs about $40 and lasts at least five years.

By the most important measure—people's health—the filters are working. "People affected by arsenicosis who have been using the filters for the last two to four years have seen their disease reverse, and they feel better," Hussam says.

Removing arsenic directly at the pump

Filtering water after people carry it home is not the only fix for arsenic contamination. SenGupta came up with a solution that traps arsenic at villagers' water sources: the tube wells.

Each tube well supplies water for about 200 families. Every day, members of these families—usually wives or daughters—head to the central tube well to fetch water. They draw it using a hand pump and then carry it home in buckets. "We thought that it was much better, more efficient, and cheaper to remove arsenic directly at the pump," SenGupta says.

SenGupta and his graduate students worked with the Bengal Engineering and Science University, Shibpur, India, to make a treatment unit that would not use electricity (since electricity is not reliable in many villages) and would be easy to operate. Most villagers collect water by going to a tube well, cranking the hand pump, and catching the water, so the new treatment unit was designed to allow villagers to collect water in the same way.


GREG ALLGOOD, PROCTER & GAMBLE

Thousands of Indian children such as Love Singh (right) have benefited from an arsenic removing powder developed by Procter & Gamble.

The treatment unit is a stainless steel column containing a substance called an adsorbent—alumina (Al_2O_3) or a polymer—which attracts other molecules to its surface and is attached to the tube well's hand pump. As a villager cranks the hand pump, the device makes water (H_2O) coming up from the well sprinkle through the air, bringing it into contact with oxygen (O_2). This oxidizes iron present in groundwater to form iron hydroxide, which separates from the water:

$$4\ Fe^{2+} + O_2 + 10\ H_2O \rightarrow 4\ Fe(OH)_3 + 8\ H^+$$

Then both iron hydroxide and adsorbent catch arsenic from the contaminated groundwater, making it safe to drink. Over 8 to 10 months, the adsorbent in the filtering devices is depleted, and the villagers need to regenerate it. They can do so by going to a central regeneration facility where the adsorbent is reactivated. The villagers also strip the filters of the trapped arsenic and package it for safe disposal.

"How you handle arsenic disposal is as important as making the water fit for drinking," SenGupta says. "For that purpose, in every village, a committee consisting mostly of women is responsible for running the day-to-day upkeep of the arsenic removal units."

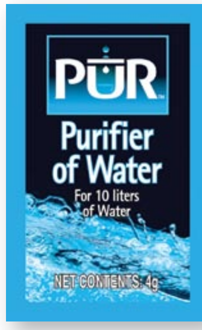
About 175 of SenGupta's hand pump filters are now already in use in India. "About 150,000 people are drinking safe water right now thanks to this hand pump filter," SenGupta says. "We want to keep that number growing!"

Arsenic-removing powder

In most industrialized countries, arsenic is usually removed from water through a water treatment plant. But building such facilities in some parts of India and Bangladesh, where hundreds of millions of people live in villages, is too expensive. Souter and his colleagues at Procter & Gamble came up with a different solution based on the same concept—small packets containing a powder that people can take with them.

"Most municipal water treatment facilities have a standard mix of chemicals that cities try to fine-tune based on local water quality," Souter says. "But people in developing countries—including India and Bangladesh—usually don't have the luxury of knowing what toxic stuff lurks in the water they need to drink. So we came up with a solution that would clean the water from arsenic, even if people don't know if there is arsenic in the water."

Souter and colleagues tested chemicals similar to the ones used in water treatment facilities but found a way to pack these chemicals into a pouch the size of a ketchup packet. Similar to what happens in large water treatment facilities, these small packets work in three steps called coagulation, flocculation, and disinfection.



PROCTER & GAMBLE

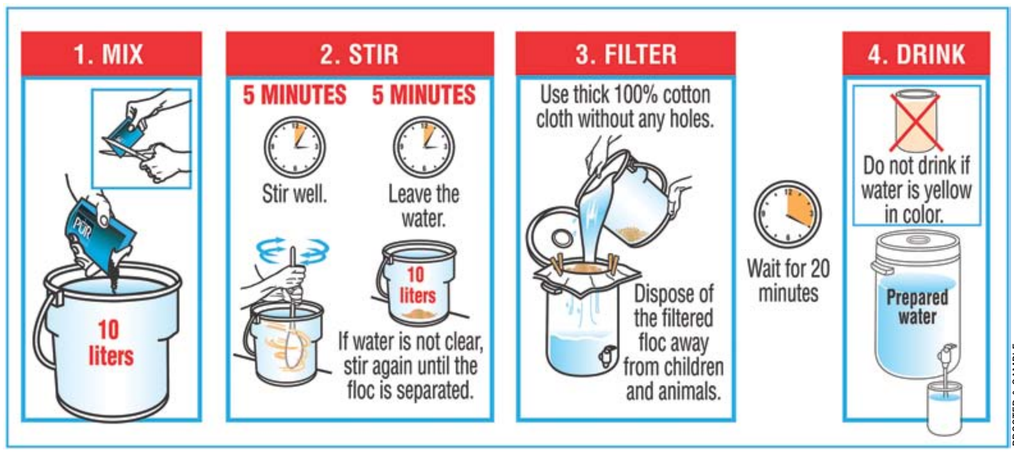
Front of the pouch containing arsenic-removing powder.

First, the contents of a packet are stirred into a bucket of water for five minutes while a chemical called ferric sulfate makes heavy metals—such as arsenic—and minerals precipitate or "coagulate" out of the water into tiny, sand-like grains.

Next, a polymer in the chemical mixture pulls the grains into big clumps, which settle at the bottom of the bucket in a process called flocculation. While the grains and clumps form, a chlorine-based disinfectant kills bacteria in the water.

The water is then poured through a clean cloth to filter out the clumps, and after 20 minutes—the time necessary for the water to be disinfected—the water is ready to drink. "Imagine the water starting out brown and foul, then finishing up clear and clean—that's how this product works," Souter says.

One packet cleans 10 liters of water—about the same amount a person can carry home from a tube well and enough drinking water for a family of four each day. Each packet costs about three cents, a price that is often paid by humanitarian groups.



PROCTER & GAMBLE

The PUR packets developed by Phil Souter and collegues work in four steps: mix, stir, filter, and drink.

ABUL K.M. MUNIR

Although many people in India and Bangladesh cannot get tap water, these three techniques are still providing them with clean water and may prevent an increasing number of them falling victim to arsenic poisoning. Sometimes, small devices with the right type of chemistry can have a tremendous impact on people's quality of life!

Christen Brownlee is a science writer at Johns Hopkins University School of Medicine's Division of Media Relations and Public Affairs, Baltimore, MD. Her article "Percy Julian: Rising Above Racism," appeared in the October 2007 issue of *ChemMatters.*

RONOCO CONSULTING CORPORATION

Sniffing Landmines

By Sarah Vos

Outside a U.S. military airbase in Kandahar, Afghanistan, eight teams of landmine detector dogs work through the desert brush searching for explosives. Insurgents had surrounded the airbase with landmines—buried explosives that blow up when a person steps on them or when a car drives over them.

Each dog works with its own handler. The dogs walk away from their handlers, sniffing in a straight line for 30 feet and then sniff their way back to the handlers, following the same line. Sometimes, one of the dogs sits and looks at a spot on the ground. By sitting, the dog indicates to the handler that an explosive is present.

Each time a dog finds a landmine, everyone else is pulled out of the area until "Explosive Ordnance Disposal" teams that are trained in handling hazardous devices containing explosive materials determine what the dog has found—an active or exploded landmine, a partial landmine, or another piece of explosive. Then they destroy any active explosives by setting them off.

In the spring of 2005, the dogs helped identify some 2,000 landmines over three months on the perimeter of the Kandahar airbase, saving human lives and clearing the way for an expansion of the base.

Throughout the world, dogs are increasingly being used to detect landmines to supplement the use of traditional metal detectors. Because of their strong sense of smell, dogs can detect very low amounts of vapor released by the landmines, thus helping to remove them safely.

PFC. RENATO LARA

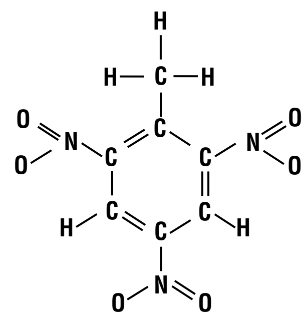
A Marine covers rear exits during a search of a residence in Rawah, Al Anbar Province, Iraq.

But not all dogs can do it and their training is uneven, prompting scientists and the federal government to develop programs to improve the training of these dogs and to find ways to select the most successful dog breeds. Other scientists have been trying to understand how dogs smell, hoping to make detectors that are as sensitive as a dog's nose in detecting explosives.

Cheap and dangerous

Landmines are cheap explosives buried close to the surface so that anyone or anything walking on them—even a dog or a child—will set them off. Landmines have been used in many war-torn countries by governments and rebel groups alike. When they explode, landmines maim and kill. Their presence cuts off access to water and prevents the use of agricultural land. They close down roads and paths and terrorize local inhabitants.

Landmines are made of a metal or a plastic casing that contains an explosive, usually the chemical trinitrotoluene (TNT).



TNT

When a landmine is set off, it causes a chemical explosion that spontaneously releases a large amount of hot gas. As the gas expands, it creates a shock wave that destroys anything it hits as it moves forward in every direction.

Near the explosion site, the shock wave from the explosion can travel as fast as 32,000 kilometers per hour (and then slows down rapidly with distance, becoming a sound wave). The shock wave causes molecules to break into fragments, which then recombine into stable gases, such as nitrogen (N_2), water (H_2O), and carbon dioxide (CO_2).

For example, when TNT ($C_7H_5N_3O_6$) is detonated, it decomposes into nitrogen (N_2), water vapor (H_2O), carbon monoxide (CO), and carbon (C):

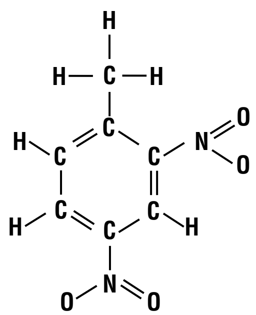
$$2\,C_7H_5N_3O_6 \rightarrow 3\,N_2 + 5\,H_2O + 7\,CO + 7\,C$$

In this case, the shock wave travels at 25,000 kilometers per hour, and the carbon forms the soot that is typical of a TNT explosion.

Escaping through the soil and into the air

When a landmine is buried underground, small amounts of the explosive inside escape through the casing either underground or into the air in the form of vapors. Dogs usually smell the vapor.

Some chemicals tend to release molecules into the air readily, making them easier to detect. This is the case with TNT, which releases an impurity called 2,4 -dinitrotoluene (DNT) that is easier to detect than TNT.



DNT


RONOCO CONSULTING CORPORATION

Landmines and unexploded munitions found in Afghanistan.

In 1998, investigators at the Canine and Detection Research Institute (CDRI) at Auburn University, Auburn, AL, used this result to show that when dogs find a TNT landmine, they actually have learned to sniff DNT—not TNT—to detect landmines. This discovery later helped in the design of instruments for detecting landmines. Auburn University has one of the most extensive and comprehensive U.S. programs of research and technology development related to the use of dogs for the detection of explosives and other hazardous materials.


RONOCO CONSULTING CORPORATION

A dog can smell chemicals up to a million times better than humans.

Dogs vs. metal detectors

The most common way to search for landmines is with metal detectors, a time-consuming process since metal detectors cannot distinguish between unexploded landmines, shrapnel, and other explosives. Also, during the past 30 years, more and more mines have been made of plastic, making metal detectors nearly unusable.

The second most common way to search for landmines is through specially trained dogs.

"Dogs can search an area a lot faster than a man with a metal detector," says Dan Hayter, president of Global Training Academy in Somerset, TX, a private company that, for the past 22 years, has been training dogs to detect bombs, mines, and drugs.

The teams working in Kandahar were supervised by Hayter. Dogs work best when they can narrow down the locations of suspected landmines, Hayter says. Then, when his teams find four or five landmines in close proximity to one another, Hayter calls metal detector teams to check the area.

The reason dogs are so successful at detecting explosives is that their sense of smell is more developed than that of humans.

"Compared to dogs, humans use their eyes more than their nose," says Paul Waggoner, director of CDRI. "Dogs are much better at smelling things but they don't use their eyes as much as humans do. They are odor-guided animals."

Scientists have shown that dogs can smell chemicals up to a million times better than humans. For example, while humans can usually smell hydrogen sulfide at a concentration as low as 10^{-6} %, or 0.000001%, a dog is able to smell that same chemical at a concentration as low as 10^{-13} %, or 0.0000000000001%.

Are landmine-detecting dogs reliable?

For the past 25 years, Larry Myers, a professor at the University of Auburn's College of Veterinary Medicine, has been trying to figure out what dogs smell. He has done experiments with explosives, illegal drugs, and substances arsonists use to start fires.

In one experiment, dogs were trained to identify gasoline. Gasoline is made up of more than 300 components, and Myers wanted to know which group of chemicals the dogs were sniffing to identify gasoline.

One year, the study showed that the dogs were tracking one group of chemicals. But the following year, Myers tested another group


RONOCO CONSULTING CORPORATION

A handler leads his dog to a demining lane to detect trace levels of explosive vapors.

of chemicals on the same dogs. Surprisingly, the dogs were able to recognize this group of chemicals as being part of gasoline. The dogs had adapted, Myers explains.

Hayter trains his dogs in the United States using TNT and other explosives. Then, once overseas, the dogs are trained on landmines that have been removed from local mine fields before being deployed to actual mine fields. When TNT has been in the ground for years, the only chemical vapor available to the dogs may be DNT, although Hayter's dogs are trained on TNT.

"DNT doesn't smell like the original TNT, which is why we first use landmines that come from active mine fields so that the dogs can get used to the smell of these landmines," Hayter says. "This learning experience is critical because it allows dogs to learn the makeup of real mines that may have been in the ground for years."

Although dogs can recognize odors and improve over time, they need to be trained for a long period of time, typically for four to six months. "In our training, we make sure that when a dog has detected the explosive, it positions itself between the mine and its handler and then it sits staring at the place where the landmine is buried," Hayter says.

In turn, handlers are trained to keep a close look at their dogs and the areas being searched to watch for potential hazards that might harm the dogs. The handlers also learn to verbally encourage the dogs to continue the search and reward them when explosives are detected.

"The relationship between the dog and the handler is crucial to make it work," Myers says. "A handler needs to constantly encourage the dog and show it his or her full attention. Otherwise, the dog gets tired and distracted and can be used as little as only two hours a day."

Mimicking a dog's nose

Because of the time and efforts needed to train dogs, scientists are now trying to develop devices that mimic the dog's sense of smell.

A dog's olfactory system—both its nose and the part of the nervous system above it that is connected to the brain—works a lot like ours. When a dog comes into contact with an odor, it sniffs it. This concentrates the odor molecules and brings them up to the receptor cells in the dog's nose. But a dog has 20 to 40 times more receptor cells than we do.

Since the early 1980s, scientists have tried to mimic what goes on in the dog's nose and brain by developing odor-detection devices that are more sensitive than current sensors to various chemicals. Although these detectors have not reached the sensitivity of a dog's nose, they are currently used not only for the detection of landmines, but also to check environmental pollution and to make perfumes.

A major project called the Unexploded Ordnance Detection and Neutralization Program, sponsored by the Defense Advanced Research Projects Agency (DARPA)—the research agency of the U.S. Department of Defense—is seeking to develop a device called an electronic dog's nose that is more sensitive than current odor-detection devices. Through this program, DARPA has been funding various university projects.

In one of those projects, led by John S. Kauer, professor of neuroscience at Tufts University, Boston, MA, scientists developed such an electronic dog's nose. The internal surfaces of this nose were covered with chemicals that interact with very low levels of various explosives.

Then, in collaboration with Waggoner and a group of scientists led by Timothy M. Swager, professor of chemistry at the Massachusetts Institute of Technology (near Boston), Kauer's team tested the device at Auburn University. From 1998 to 2003, the researchers studied the sensitivity of various chemicals in the nose to DNT and TNT and found that an electronic nose covered with polymers was as sensitive as—and sometimes even slightly more sensitive than—a dog's nose. These experiments also allowed the scientists to make a computer simulation of how a dog's nose detects and discriminates various chemicals.

SGT. KEVIN L. MOSES SR.

U.S. soldiers and Iraqi soldiers conduct joint patrols in Ameriyah, Iraq. U.S. Army Spc. Robert Dami and his working dog Jay search a home for explosives.

Another team of scientists led by Gary S. Settles, professor of mechanical engineering at Penn State University, University Park, PA, is studying the airflow inside a dog nose to understand how the nose samples the air and detects very small amounts of chemicals. Settles and colleagues (who had been previously involved in Kauer's project as well) are trying to understand in detail how chemicals flow in the dog's nostrils and how the hair inside the nostrils detect chemicals and relay that information to the brain. Settles and colleagues are now using their results to simulate a detector that works the same way.

Better dogs

While research to develop an electronic dog nose and similar devices is ongoing, other efforts seek to improve the training of dogs because training programs throughout the world and across the United States vary in quality and efficiency.

The Geneva International Centre for Humanitarian Demining, a United Nations organization specializing in mine clearance and victim assistance, has developed procedures to improve the efficiency of dog training programs. These procedures suggest choosing certain breeds of dogs that are more successful than others at detecting landmines.

At Auburn University, Myers is developing a program to make landmine-detecting dogs more reliable. Although the program has not been funded yet, its goal is to optimize dog training by looking at the best ways to both stimulate the dogs and teach the handlers how to work efficiently with their assigned dogs.

JUPITER IMAGES

"The information collected over the past three decades about how these dogs behave is now helping us to devise more rigorous ways to train these dogs," Myers says. "If this program is funded, we should be able to provide guidelines to make dog training programs more consistent and more successful."

REFERENCES

Guide to Mine Action and Explosive Remnant of War by The Geneva International Centre for Humanitarian Demining. http://www.gichd.org

Global Training Academy, Somerset, Texas. http://www.k9gta.com

Phelan, James M. and Webb, Stephen. Chemical Sensing for Buried Landmines—Fundamental Processes Influencing Trace Chemical Detection. Sandia National Laboratories: Albuquerque, NM, May 2002.

Jenkins, T. F., et al. Chemical signatures of TNT-filled land mines. *Talanta* **2001**, *54*, 501–513.

Sarah Vos is a reporter for the *Lexington Herald-Leader* in Lexington, KY. Her most recent *ChemMatters* article, "Linus Pauling, American Hero," appeared in the October 2007 issue.

CHEM.MATTERS.LINKS

The quest for a clean drink

The United Nations reports that 4,400 children under the age of 5 die every day around the world because of unclean water and sanitation. Learn more about this water crisis and the efforts of hip hop artist Jay-Z to promote awareness of this issue at **http://www.un.org/works/water/index.html** (also includes a **lesson plan for teachers**).

More information about Abul Hussam, the winner of a $1 million prize for the invention of a cheap, easy-to-use filter that provides arsenic-free drinking water to thousands of people in Bangladesh: **http://chemistry.gmu.edu/faculty/hussam/index.html.**

Sniffing landmines

Scientific American Frontiers tells you more about landmines, the dog's sense of smell, and electronic dog noses at **http://www.pbs.org/saf/1201/** (also includes a teaching guide).

Women and chemistry

Biographies of women chemists who have left their mark in chemistry from The Chemical Heritage Foundation's Women in Chemistry Web site: **http://www.chemheritage.org/women_chemistry/know/lyon_carr.html.**

The chemistry of arson investigation

The latest news on arson investigations throughout the world and more can be found on the International Association of Arson Investigators' Web site: **http://www.firearson.com/insideiaai/featuredtopics/index.asp.**

The latest results from Aura

Aura belongs to a series of five satellites, called the A-train, flying in close proximity. Learn about how these satellites complement each other by collecting data about the chemicals present in the atmosphere: **http://www-calipso.larc.nasa.gov/about/atrain.php.**

Interview with Nobel Prize winner Gerhard Ertl

Information for a lay audience about Gerhard Ertl's scientific achievements from the Royal Swedish Academy of Sciences: **http://nobelprize.org/nobel_prizes/chemistry/laureates/2007/info.pdf.**

Celebrate Earth Day on April 22

To celebrate this year's Earth Day (April 22) and its water-based theme, "Streaming Chemistry," the American Chemical Society encourages you to clean up and keep clean a section of a stream or waterway. You are also invited to participate in a haiku poem contest. Submit entries to your ACS local contact. Winners will be entered in the national contest and the national winner will be announced on Earth Day. More information about Earth Day is available at **www.acs.org/earthday** and **http://ww2.earthday.net/~earthday/.**

Interested in winning $10,000?

Apply for a Lemelson-MIT InvenTeams grant and receive up to $10,000 for a team of high school students, teachers, and mentors to identify a problem and invent a solution for it. Up to 35 applicants from the initial application round will be named Excite Award recipients. These recipients will be invited to attend workshops at MIT, June 26–27, 2007 (all expenses paid) to learn first-hand about invention and the InvenTeams experience and receive guidance to develop the final application. Initial applications are due April 25, 2008; apply at **http://web.mit.edu/inventeams** or e-mail questions to inventeams@mit.edu.

In every issue of *ChemMatters*, one of the articles is now translated in Spanish! Available online at www.acs.org/chemmatters.

CM Demystifying Everyday Chemistry

1155 Sixteenth Street, NW
Washington, DC 20036-4800

Reach us on the Web at www.acs.org/chemmatters

A publication of the Education Division of the American Chemical Society